Comprehensive Everglades Restoration Plan
Monitoring and Assessment Plan

Table of Contents

Section I. Introduction and Background
1. Purpose of the Monitoring and Assessment Plan
2. What are Monitoring and Assessment?
3. What should be Monitored?
    In General
    AET/Restudy
    Conceptual Ecological Models
    Water Quality
    Selection of Performance Measures for this Plan
4. Monitoring and Assessment Plan Design Strategy
5. How are Monitoring Data Managed and Analyzed?
6. How are Monitoring Data used to assess CERP Performance?
7. Implementation of the Plan
8. Uncertainties in System Responses
9. Perspectives on Successful Restoration
10. Adaptive Assessment Team Editorial Team Members

Section II. Conceptual Ecological Models

Section III. Monitoring Parameters and Performance Measure Documentation Sheets

Section IV. Research Needs in Support of the CERP Monitoring and Assessment Plan

Section V. Annual Spread Sheets for Tracking Monitoring

I. Introduction and Background

The Comprehensive Everglades Restoration Plan (CERP) monitoring and assessment plan is a product of an interagency, interdisciplinary team known as Restoration Coordination and Verification (RECOVER). The Adaptive Assessment Team (AAT) of RECOVER has the lead responsibility for creating the monitoring and assessment plan, and for conducting an on-going review of how well it is working. In addition, the AAT has the responsibility to use the information that is provided by the monitoring program to assess system responses, as a basis for recommending improvements in the restoration plan where needed. Overall, the RECOVER Leadership Group holds accountability for the CERP monitoring and assessment program within RECOVER.

(1) Purpose of the Monitoring and Assessment Plan

The primary purpose of this monitoring and assessment plan is to identify and describe the performance measures and parameters of the natural and human systems in south Florida that should be measured in order to determine the success of the CERP. The goal is to create a single, integrated, system-wide monitoring and assessment program that will be used and supported by all participating agencies as the means for tracking and measuring the success of the Comprehensive Plan. This document identifies the specific set of physical and biological performance measures that should be monitored, the geographic regions where these measures should be monitored, and the improvements in these measures that should occur during and following the implementation of the Comprehensive Plan. Collectively these measures will serve as indicators of the overall health of natural and human systems in south Florida, relative to the objectives of CERP. This monitoring and assessment program is required as a basis for determining whether CERP achieves these objectives (i.e., the recovery of healthy and sustainable ecosystems throughout south Florida and an improved environment for people), and to support an adaptive assessment process for refining and improving the design and operation of CERP throughout its implementation.

This is a system-wide monitoring and assessment program, designed solely for assessing how well CERP meets the system-wide objectives of ecosystem restoration and water supply. Each CERP project will develop a separate, local monitoring plan to assess the success of the individual project. To ensure that measures and targets selected by the project teams are consistent with system-wide measures, each project team should review this system-wide plan.

As a prerequisite to the implementation of the CERP monitoring and assessment plan, RECOVER is preparing four additional planning documents that will substantially expand upon the summaries provided below. These are:

1) an integrated and standardized system-wide sampling design and data management protocol for the monitoring plan (subsection 4);
2) an adaptive assessment strategy explaining how the AAT will use the monitoring data to conduct annual assessments of system-wide responses (subsection 6);
3) a detailed monitoring plan implementation strategy (subsection 7); and
4) a research needs document in support of the monitoring and assessment plan (Section IV).

In addition to these four planning documents, RECOVER prepares (and revises annually) a Program Management Plan. This management plan describes the tasks and responsibilities for all South Florida Water Management District and U.S. Army Corps of Engineers activities pertaining to RECOVER for a three-year planning period. The RECOVER management plan includes a budget for all monitoring and assessment tasks.

The CERP monitoring and assessment plan is organized into five sections. Section I, the Introduction and Background, provides a broad overview of the purpose of the monitoring plan, how it was created, and how it should be applied. Section II contains the narrative descriptions and flow diagrams for the set of nine conceptual ecological

models that provide the technical foundation for most of the natural system performance measures that have been incorporated into the monitoring plan. Section III contains the technical documentation sheets for each of the CERP performance measures that make up the monitoring plan. This section includes a description of the process used to develop and screen the biologic, hydrologic, and water quality performance measures comprising the CERP monitoring and assessment plan. These documentation sheets identify the specific parameters of the natural and human systems that are to be monitored, the geographic region where each is to be monitored, and the restoration targets for each. Section IV is a summary of the uncertainties associated with the hypotheses in the ecological conceptual models and a recommendation for research needs in support of CERP. The research listing identifies studies needed to reduce uncertainties in the model hypotheses in order to improve the ability of RECOVER teams to predict and interpret system responses. Section V is a set of spreadsheets, to be revised annually, for purposes of tracking the status of each element in the monitoring plan.[1] Additional information on the content of each section is provided in the introductory paragraphs for each of the subsequent sections. Specific monitoring protocols, i.e., how the elements should be monitored individually and collectively, will be determined through consultation with the agency(s) or organizations responsible for implementing the data management program and the elements of the monitoring plan as well as outside consultants.

The content and adequacy of the CERP monitoring and assessment plan will be regularly reviewed by the AAT and the full RECOVER team, by all participating agencies, and by independent reviewers. Changes in the monitoring and assessment plan will be approved by the AAT. During the initial reviews of the monitoring plan the number and focus of the performance measures may be revised, due to on-going efforts to maximize the efficiency and coverage of the monitoring effort, while at the same time attempting to settle on the smallest number of measures necessary to track system-wide responses to CERP. As part of this initial review, the AAT will continue to examine the biological performance measures that are contained in this draft. The objective of this continuing review is to insure that the biological measures have been carefully selected and designed to effectively track responses by the components of the key restoration hypotheses contained in the conceptual ecological models. However, once the initial monitoring and assessment plan is reviewed and approved, it is not expected that large-scale changes will occur or would be desirable.

(2) What are Monitoring and Assessment?

Monitoring and assessment are critical components in the CERP adaptive assessment protocol and as such, merit clear definitions. Monitoring is the systematic process of collecting and storing data related to particular natural and human systems at some specified locations and times. Assessment is the process whereby monitoring data are interpreted in the context of particular questions and issues, such as tracking progress towards certain restoration objectives. Assessment also includes the development of statistical relationships from the monitoring data, other model development and application, and cause-effect research linked directly to the objectives of the restoration

[1] Note that this section is not included in this review draft of the monitoring and assessment plan.

program. Monitoring can be used to document the status and trends of elements within the ecosystem over a range of temporal and spatial scales, and provide feedback that can be used to assess whether the predicted results are being achieved. It also provides information that can be used to help refine or modify actions to ensure that the targets for the project are being met.

When applied to natural ecosystems where maintenance in their current condition is desired, monitoring can be used to evaluate whether there are aspects of the ecosystem that are varying beyond what would be expected under the influence of natural processes. When monitoring is applied to disturbed ecosystems that are being restored, monitoring can be used to evaluate whether the ecosystem is moving in the desired direction. Monitoring can also determine when the ecosystem has moved within the bounds of what is defined as the restored condition.

It is important to be aware that rates of change, and thus the time required to document them, are often very different depending on the element being measured. Site history, landscape setting, the kind, degree, and direction of change, the potential rates of change for each parameter, and the level of applied effort in restoration projects can all affect rates of change. Restoration of some disturbed ecosystems can only be considered in geologic time frames because of the degree of disturbance that has occurred on these sites. In addition, other aspects of the South Florida ecosystem, including both restoration and development activities, will inevitably be changing at the same time, further complicating the ability to assess the success of the individual restoration components. It is essential that these differences in rates of change be factored into the assessments of environmental responses.

In the context of RECOVER, monitoring has been defined in an adaptive assessment strategy (An Adaptive Assessment Strategy for the Comprehensive Everglades Restoration Plan; AAT, 2000) as having four objectives:

1) Establish base-line variability for each of the performance measures;
2) Determine the status and trends among the performance measures;
3) Detect unexpected responses for components or measures of the ecosystem that have not been specifically identified as CERP performance measures; and
4) Cause-and-effect scientific investigations designed to increase ecosystem understanding, particularly if restoration implementation yields unanticipated results.

Addressing these objectives will allow the determination of how CERP is affecting the physical, biological, and chemical components of the system, and to increase scientific understanding of how the system works. Knowledge of how the system is changing in response to CERP restoration actions combined with investigations of cause-and-effect relationships will contribute to the refinement of CERP projects to ensure that targets are being met. It is recognized that this monitoring plan does not include all of the measures necessary to document the long-term “restoration” of all systems in south Florida (e.g.,

some upland systems in undeveloped and developed landscapes), but it will provide a minimal set of measures for those systems directly affected by CERP.

(3) What Should Be Monitored?

In General

The main point of environmental monitoring is to detect change or lack of change over time, and to provide information sufficient to understand the causes of these patterns so that appropriate actions can be taken to manage the ecosystem for a desired condition. Part of the challenge in designing and sustaining a successful monitoring program is to select a limited set of parameters that adequately convey whether the ecosystem is or is not changing, in what direction it is changing, whether these changes are natural or a result of human actions, and if the latter, whether the changes improve or adversely affect the ecosystem in some significant way.

Prior to determining whether a change in condition or state has occurred, it is necessary to establish the initial or baseline conditions. Baseline information provides the benchmark against which the progress of the restoration plan can be measured, and to understand the ranges of natural variability necessary to confirm when change has actually occurred. While some regions of the Everglades ecosystem have well established monitoring programs, other areas have little or no baseline data. Plugging the gaps in baseline conditions is one of the critical components of the monitoring and assessment plan.

There are different approaches that can be used for selecting the best suite of monitoring parameters. One can select parameters that are considered to be the major stressors or processes that control the context within which an ecosystem operates. With this approach it is assumed that as long as the major processes are operating appropriately, the ecosystem is functioning appropriately.

Alternately, parameters such as individual species or groups of species that are considered to be indicators of the processes operating within the ecosystem can be selected. This approach assumes that unless all of the significant processes are operating appropriately, these indicators could not exist in this ecosystem at normal population levels.

This mix of constraints on the ability to detect either desirable change resulting from restoration or undesirable change in an ecosystem argues for monitoring a mix of both basic processes and integrators. This and the ever-present possibility of unanticipated ecosystem changes also argue for the use of as many monitoring parameters as are "feasible" from as broad a spectrum of ecosystem parameters as possible. In practical terms, "feasible" means that there are good assurances that the parameters can be measured and understood over sufficient time periods to determine the long-term affects of management or a restoration program.

The performance measures in this monitoring plan are planning and assessment tools that were approved (and in most cases also developed) by the CERP planning teams to identify the objectives for the restoration plan. Each performance measure identifies one or more components of the natural and human systems in south Florida that CERP has been designed to improve. The performance measures may be used in evaluation of proposed changes (primarily where simulation models exist) and as field indicators that the appropriate change has occurred.

These performance measures have, for the most part, been selected through two CERP planning processes; 1) the C&SF Project Comprehensive Review Study's (Restudy) Alternative Evaluation Team (AET) and 2) the RECOVER Regional Evaluation, Adaptive Assessment, and Water Quality teams.

Restudy/AET process

Between 1996 – 1999, during the Restudy feasibility phase of CERP, an interdisciplinary, interagency team of biologists, ecologists, and other resource specialists (AET) developed a set of performance measures as the basis for designing and evaluating alternative restoration plans. Each performance measure was implicitly linked to one or more planning objectives, and consisted of a measurable indicator and target. Because a key tenet of south Florida ecosystem restoration is that hydrologic restoration is a necessary starting point for ecological restoration, the performance measures created by the AET were largely indicators of hydrologic characteristics, consistent with what is known or hypothesized about the optimum hydrologic patterns for a number of characteristic plant and animal communities in the historic Everglades.

These performance measures described hydrological parameters, data format and hydrological targets originally used by the AET to evaluate hydrologic simulation of alternative plans. Refined versions of these hydrologic performance measures are included in this monitoring plan for their value in setting hydrological targets for CERP, and for evaluating how well CERP implementation corrects the hydrological problems in the natural and human systems.

Conceptual Model process

The Restudy included an Applied Science Strategy that will now be used to link science and management during all phases of CERP. An essential step in this strategy has been the creation and refinement of a set of nine conceptual ecological models, each for a different physiographic region of south Florida. The models link stressors on the ecosystem to ecological attributes that are considered to be indicators of ecosystem health. Each of these linkages represents a working hypothesis based upon current knowledge of the ecosystem.

The overall Restudy strategy was to use the conceptual models as a basis for reducing the total number of performance measures from an almost infinite number of potential measures in the natural and human systems of south Florida to a manageable number of

major key indicators of environmental conditions. The models allowed for the selection of a parsimonious set of performance measures directly based on the stressors and attributes in each model. These measures collectively describe the physical and biological conditions that will be used to define a successfully restored natural system.

The rationale for having performance measures and targets for each stressor is that the stressors are known or hypothesized to be the immediate sources of the ecological problems in each landscape. A successful restoration program must eliminate the unnatural stresssors acting on the natural systems. A performance measure describes the stressor and how that stressor should be measured, and how that stressor must change in order to neutralize its adverse effects. The hydrological performance measures for the natural system that were developed by the AET were for the most part derived from the hydrological stressors in these models.

Performance measures have also been developed for each attribute in the conceptual models. The attributes have been identified as the biological or ecological elements that are the best indicators of responses in the natural systems to the adverse effects of the stressors. The hypotheses used to construct the conceptual models link each attribute to the stressor(s) that are most responsible for change in that attribute. If the hypotheses are correct, neutralizing the adverse affects of the stressor will result in a predictable positive response by the attribute. The performance measure developed for each attribute identifies the element(s) of that attribute that should respond, how the element(s) should be measured, and how the element(s) should change once the effects of the stressor are removed.

The conceptual models also were used to identify uncertainties in knowledge in the linkages among the stressors and attributes. These uncertainties identify where additional research is needed to ensure the success of CERP and is discussed in Section IV.

Development of Water Quality Performance Measures

A number of the performance measures developed during the Restudy/AET process specifically focused on water quality. Water quality is identified as a stressor in several of the conceptual models. The linkages between water quality, hydrology and biology are complex and led to the decision to create a team that focuses on water quality as part of the RECOVER process. Refinement of water quality performance measures for RECOVER were conducted through the application of water quality and landscape models, empirical analyses, and results of on-going research.

Selection of performance measures for this plan

Over 900 performance measures and indicators resulted from the above processes. The monitoring and assessment plan must be sustainable for perhaps five decades or longer if it is to be successful in guiding CERP throughout its implementation and subsequent operation. The high cost of monitoring a large number of parameters over a large area and a long period of time is a major reason that many monitoring plans in support of

adaptive assessment and management have failed to be sustainable. Therefore, it is crucial to identify a minimum set of performance measures that will indicate whether CERP is achieving ecological recovery of the greater Everglades ecosystem and is meeting its water supply and flood protection objectives.

Determining this minimum set of parameters from the many performance measures that were proposed was one of the tasks of the AAT's Editorial Team. This task was accomplished by organizing the submitted performance measures into broad categories, and reviewing the performance measures in each category to determine where overlapping measures could be combined. Measures were combined when two or more had similar locations, parameters or targets (see Section III for details). The result is a list of ~150 performance measures (~60 biological and soils, ~20 hydrological and ~70 water quality) with identification of the information they provide to assess system-wide CERP performance.

The refinement of the performance measures is an on-going process. It is essential that the monitoring and assessment plan address the key restoration hypotheses, and that it focus on a sustainable number of performance measures. Long-term monitoring and assessment efforts fail if they are too large, too complicated, too expensive, or if the results can not be interpreted within the context of the key hypotheses. The next steps in the evolution of this monitoring and assessment plan is for the Adaptive Assessment team to re-exam the current set of recommended measures in the context of their linkages as outlined in the conceptual models. As part of this review, the measures will be grouped into logical, hypothesis-based packages as a basis for designing a more efficient system-wide monitoring protocol. The selection of these key hypotheses provides the focus for the monitoring and assessment program and for setting hypothesis-driven priorities in on-going and future natural systems research. The ultimate success of the CERP adaptive assessment program will depend on the acquisition of new information from an integrated program of modeling, monitoring and hypothesis-driven research. The general framework for this approach is further outlined in Section III of this monitoring and assessment plan.

(4) Monitoring Plan Design Strategy: Monitoring design considerations

Along with the identification of essential parameters to monitor, a monitoring network must be logistically economical, provide quantitative data, apply a standardized monitoring and data management protocol, and ensure that data analysis is done in ways insure that trends can be correctly recognized and tracked over time with confidence. There are a number of different approaches that can be taken in the design of a monitoring network that meets these design objectives. Although decisions regarding the details of the design protocol have yet to be determined, certain guiding considerations are provided here.

Field monitoring and laboratory methods must be standardized. All participating investigators in the monitoring and assessment program must use agreed-upon methods

for collecting and managing monitoring data. Any changes in methods during the implementation of the monitoring and assessment plan will be documented.

A spatial framework for the monitoring network and its component performance measures needs to be defined. Selection of performance measures can best be done within this framework because: 1) the spatial scale of sampling will financially constrain the number of parameters that can be measured; 2) consideration of spatial domains that are consistent with the conceptual models will promote consideration of the interactions of performance measures and the need for grouping measures, rather than assessing measures independently; and 3) consideration of gradients will add realism to the conceptual model approach – the habitats included in the conceptual models are not isolated entities, but rather exist as part of a continuum across the landscape. Common performance measures of several habitats and how they change temporally across habitat ecotones needs to be assessed.

RECOVER should consider documenting changes across three important gradients that will be changed during the restoration: hydrologic, nutrient, and salinity gradients.

- Hydrologic gradients – restoration will change the spatial distribution of hydropatterns and associated plant and animal communities. Gradients from uplands through deeply inundated wetlands may shift over substantial distances.
- Nutrient gradients – must be able to detect effectiveness of water quality improvements in and near impacted zones, which generally are gradients oriented by discharge sources. Indirect hydrological effects on natural nutrient gradients must also be assessed (e.g. within mangrove zone).
- Salinity gradients – changing water quantity, distribution, and timing will cause changes in the location of salinity gradients and the salinity patterns along those gradients. This will yield biological responses that can best be assessed by sampling along these gradients.

Several monitoring design options are available. These options are not mutually exclusive, but each should be carefully assessed as to their advantages and disadvantages prior to selecting a design. Transects are an excellent approach toward assessing changes along gradients. These gradients are the most likely locations where ecological change will occur; transects maximize the ability to detect this change. A randomized design (like the EPA EMAP) or stratified randomized design is capable of spatially integrating broad-scale changes for the entire landscape area . This design is desirable if a broad spatial integration is the highest priority. A network of fixed stations that are based on existing monitoring networks can provide a larger data time series for comparison with post-restoration conditions (e.g. hydrological and water quality). Sites of special interest will provide information relative to unique species or communities and how they are affected by restoration (e.g. within selected reference or indicator areas).

If a transect design is chosen, sampling along gradients can either be completely randomized or stratified random sampling (depending on steepness of gradient or on habitat type); sample sites can be fixed for some parameters (with randomized initial selection) such as for ground water wells or individual trees. Likewise, if the focus is on

indicator regions, sampling within these regions can be randomized or transect based (assuming these regions span recognizable gradients).

Existing monitoring networks or sites (especially hydrologic and water quality sites) may be incorporated into the CERP monitoring program, to the maximum extent possible and consistent with the purposes of the existing programs. While there is a need to utilize historical data to assess long-term change, the CERP network should not be based on the existing network if this design is not appropriate for future needs.

A network of "indicator regions" created by the AET, and refined by the RECOVER Regional Evaluation Team, should be considered in the spatial design of the monitoring plan. Indicator regions are select groupings of cells (2-mile x 2-mile grid) within the Natural System Model and the South Florida Water Management Model. Each of the indicator regions was chosen on the basis of having relatively uniform hydrologic and vegetation characteristics. The indicator regions were used in simulation modeling to average model output over multiple similar cells as a way of reducing analytical uncertainties associated with single cell comparisons. The current set of indicator regions may provide preferred locations for a network of monitoring stations throughout the CERP restoration area.

Monitoring and research spatial design should be integrated. It is not efficient to have separate designs for hydrologic, water quality, and biological networks – these should be part of an integrated monitoring system to the extent possible. Because of the importance of this integration, it may be necessary to change the existing hydrologic and water quality network or the indicator region selections. Large-scale integration should be explored using aerial photography and remote sensing.

(5) How are monitoring data managed and analyzed?

The scientific and technical information generated from the system-wide monitoring and assessment program must be organized and analyzed in such a fashion to allow RECOVER to effectively evaluate CERP performance and system responses and to produce an annual assessment report describing and interpreting the responses. Development of appropriate database systems, data analysis protocols and outputs, and a data driven web interface are key to the successful implementation of the adaptive assessment process.

The design of the CERP monitoring data management and analysis system will be based on knowledge gained from the successful data management systems currently being used in several on-going regional monitoring programs in south Florida, including the Kissimmee River restoration program and the Lake Okeechobee ecological data-bases.

The data management and analysis system used to organize and archive data and reports generated from the system-wide monitoring program will be part of a centralized CERP shared data and information network infrastructure. This system will be designed and developed so that it integrates with other database components of the infrastructure. With

guidance and direction from the AAT, the monitoring data management system will be evaluated, designed, developed, tested and implemented within the CERP Data Management Program. Additionally, appropriate user web-based interface tools to display and analyze the monitoring data will be designed and developed.

A separate program-level management and analysis plan for all CERP-related data will include the information technology necessary to collect, store and retrieve and analyze the data. The data management plan will describe the scope, schedule and costs associated with design, procurement, installation and configuration of the hardware, software, network, security and data communication lines that comprise the shared data and information network. The appropriate protocol and procedures for tracking and storing all documents, data and records needs to be established in the plan as well.

The data management and analysis system will be designed to facilitate electronic storage and retrieval of environmental data and reports as well as provide access to other information (modeling, socio-economic, costs and schedules, etc.) that may be needed to assess CERP performance. The system will be equally accessible to the SFWMD, the USACE and other participating agencies, and will consist of database servers and a web site that will allow a multitude of data types and relevant documents to be easily accessed and shared. The infrastructure and software will be designed to eliminate the potential for security and firewall breaches that could threaten the integrity of the system and the information it contains. The web site will also be used to post information and data for review by other agencies, stakeholder groups and the public.

The monitoring program database will contain all environmental (hydrologic, water quality, and biological) monitoring spatial and time series data tables that will be used to assess the effects of implementing CERP. The database will store documents, imagery and other tables (such as those that describe methods, conceptual models, performance measures, costs, etc.) that are needed to interpret or enhance understanding of the environmental data. Development of the database hinges on continued evolution of the conceptual models and listing of associated performance measures and monitoring needs to guide the process.

System development will also require acquisition/capture from multiple sources (CERP projects, external agencies, SFWMD, etc.) and inventory of all existing (and future) data that may be relevant to the performance measures. Types of data to be captured and archived in the system include: metadata, geospatial, time series, operations, engineering/construction designs, and technical reports/relevant research. Geospatial data includes, but is not limited to, surveys, maps, aerial photography, aerial imagery, and modeling coverages (biological, water quality and hydrological). There is a considerable amount of time series data generated from a number of on-going monitoring and research programs that will also need to be incorporated into the system.

To effectively manage these data and ensure that they can be easily stored, accessed and retrieved, and transferred by all authorized users, a set of standards, processes, procedures and tools will be established. The standards and procedures will address such topics as

geospatial metadata, data projections, horizontal/vertical datums, file formats, compression techniques, file coding and file naming conventions for all data to be stored on the shared data and information network. A document management and control system/process will be developed and implemented to assist with organizing and tracking program documents and reports.

A quality assessment/quality control (QA/QC) process will be established to ensure that data generated from the monitoring program are checked for the proper integrity before being archived into the shared database.

The database system will be maintained, updated, quality assured and expanded to meet the needs of the adaptive assessment process, as necessary, and to accommodate continuous acquisition, storage, analysis and publishing of data. The system will require periodic hardware and software upgrades, along with possible purchase of additional disk space and memory.

A key component in a successful data management system is data analysis. The management system must produce data reports that present the monitoring data in formats that clearly support the Adaptive Assessment team in its task of interpreting system responses in the context of restoration targets. For this to happen, the raw monitoring data for each of the performance measures must be analyzed according to a protocol that is consistent with the guiding hypotheses and the restoration targets. The Adaptive Assessment team will have a lead role in determining the requirements for the design for data analysis for each of the performance measures, and for determining the required formats for the data reports.

(6) How are monitoring data used to assess CERP performance?

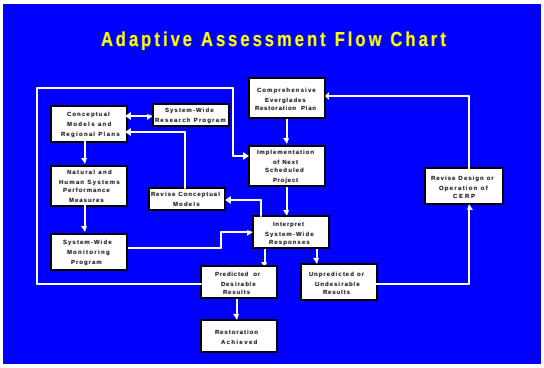
The monitoring data will be analyzed, and used to support an adaptive assessment protocol that has been established in CERP as a means for tracking the results of CERP, and for improving its design and operation whenever unexpected and/or undesirable responses occur. The assessment will follow the protocol developed by the AAT (AAT 2000; Figure X). The actual responses that occur in the natural and human systems during and following the implementation of CERP will be compared to the trends and targets that have been established for each performance measure. These comparisons will serve as a basis for determining how successfully the CERP projects, individually and collectively, are moving these systems towards the plan's overall goals. It will be the combined responses from the full set of performance measures that will determine the overall success of CERP.

The CERP monitoring program is designed to track the responses by each of the restoration plan's performance measures. Empirical data from the monitoring program is fed into the CERP data management system. This data management system will convert the field data into formats that can be used by the RECOVER teams to interpret system responses to the CERP projects. Data management will include synthesis and analysis of

the monitoring data, in order to create the data reports that will best support the assessment process.

Data analysis is an essential prerequisite to the task of interpreting system responses. Raw monitoring data must be converted into formats and reports that reveal the status and trends, patterns of variability, and probable responses to the effects of CERP, for each of the performance measures.

The AAT has the lead responsibility for reviewing and interpreting the analyzed outputs



from the monitoring data, and for integrating new knowledge of the natural systems into the assessment process, as a basis for tracking the success of CERP. A protocol will be developed that not only examines monitoring data for each of the individual performance measures, but also integrates these into an overall assessment of system health/integrity. The AAT will issue annually a report on the performance of CERP. These reports will identify where ecosystem responses to CERP are on track to meet the goals of the plan, and/or where undesirable responses are being detected. Where undesirable responses occur, or may be anticipated based on initial interpretations of monitoring and research data, the annual reports will suggest whether the causes of these responses are due to some structural or operational component of the restoration plan or are external to the plan. The Comprehensive Plan Refinement Team of RECOVER will use these AAT reports as a basis for coordinating efforts to recommend solutions to any problems in CERP's performance.

(7) Implementation of the Plan

The CERP monitoring program consists of approximately 150 different biological, hydrological and water quality parameters. No single agency can or should have responsibility for conducting the full suite of monitoring tasks. Although lead responsibility for funding and implementing this monitoring program is held by the USACE and the SFWMD, the success of this program will depend on a long-term participation by a number of different south Florida resource agencies. Following are suggested guidelines for some of the tactical steps required to implement the CERP monitoring program. Some of these steps are, by necessity, sequential but many may be conducted simultaneously.

Selection of Performance Measures

- Determine the parameters of the natural and human systems in south Florida to be monitored, those which will best measure the success of CERP.

Peer Review of Plan

- Conduct an internal review of the monitoring plan within the SFWMD and USACE.
- Provide for external peer review of the monitoring plan (SCT, CROGEE).
- Introduce the monitoring plan to the south Florida agencies through the agency representatives on RECOVER, and through the South Florida Ecosystem Restoration Working Group.
- Facilitate agency reviews of the monitoring plan.

Monitoring Network Spatial and Temporal Design

- Review and evaluate regional monitoring programs for other large restoration efforts for their extent, operational protocols, data management processes, and funding basis relative to long-term needs of CERP (LTR program, EMAP, Kissimmee River, etc.).
- Bring in experts on monitoring network development and design methods, as well as on evaluating and determining monitoring methods and protocols for each performance measure.
- Identify the elements of the CERP monitoring program that are currently being monitored by one or more agencies, and incorporate, to the extent practical, these existing monitoring networks and infrastructure to achieve the objectives of adaptive assessment, while still meeting individual agency needs.
- Lay out and optimize the network at spatial scales and over time periods that are consistent with the scales of the implementation schedule for CERP and the expected system responses.

Monitoring Network Implementation Flexibility

- Design and implement the monitoring program with monitoring stations being phased in over the next one to three years.
- Where appropriate, refine and redirect existing environmental monitoring to better focus on needs of CERP.
- Identify monitoring gaps.
- Create a monitoring schedule, based on a prioritization process that focuses first on integrating existing monitoring programs and on new baselines (where none exist) that need to be established prior to implementation of the restoration program.

Capture and Inventory Historical Data for Performance Measures

- Conduct an inventory/analysis of existing historical performance measure data and determine a process for acquiring the data, evaluating its quality and organizing it for archival in the CERP data management system.

Assign Monitoring Responsibilities

- Assess the type and extent of external agency involvement in the implementation of monitoring tasks and determine which agency will be responsible for monitoring what performance measures and where.
- Assign to an appropriate entity, the responsibility for general oversight of the day-to-day operations and maintenance of the overall system.

Establish Standard Operating Procedures

- Develop protocols and standard operation procedures for data collection (i.e. sampling methods for each performance measure), instrumentation, data processing, lab analysis, quality control and assurance, flow and load calculation methods, and reporting format/schedule.
- Work with CERP Data Management Program team to establish a set of standards, process procedures and tools to effectively quality assure/quality control data and ensure it can be easily stored, accessed and retrieved, and transferred. Such standards and procedures include those for data validation and formatting criteria, station naming conventions, and metadata requirements (e.g., site registration, GPS coordinates, vertical datum, etc.) for the performance measures.

Integrate Program with Research and Projects

- Integrate RECOVER monitoring and assessment program with other research and modeling efforts and develop linkages between the RECOVER monitoring and project-specific monitoring.

Procurement Strategy

- Develop a SFWMD/USACE procurement strategy for monitoring services and resources that includes identification of outsourcing opportunities and possible M/WBE vendors and contractors
- Pre-qualify expertise of contractors.
- Develop standard scopes of work for MOUs, MOAs, contracts etc. with agencies and laboratories that will be collecting and analyzing data for the system-wide monitoring network.
- Outline a prioritization schedule for procuring required monitoring system instrumentation (telemetry, CR10s, autosamplers, etc.) and other capital needs as each phase of monitoring is implemented.

Review and Assess Effectiveness of Monitoring Program

- Conduct annual reviews of the monitoring program to determine the effectiveness of the program for measuring system responses and supporting an adaptive assessment process. The plan will be periodically fine tuned on a scientifically informed basis,

including refining and enhancing performance measures to optimize the network, as needed.

- The AAT will prepare an annual adaptive assessment report on system responses, and will identify where CERP refinement may be needed.

(8) Uncertainties in system responses

In the development and selection of performance measures and the resultant monitoring and assessment plan, there are varying degrees of certainty regarding the expected system response as we construct and operate the various CERP projects. Performance measures derived from predictive models that have been calibrated and verified with empirical data, or through cause-and-effect experimentation, provide the most certainty as to their accuracy. However, this type of in-depth analysis and documentation of ecological processes is not routine or uniform across the ecosystem. Many of the performance measures are based on indirect, correlative approaches or best professional judgement. Therefore, it is anticipated that unexpected or "negative" responses may occur as we move through the CERP program.

To illustrate, each conceptual model for CERP links ecosystem stressors to attributes via a series of causal pathways. The linkages between stressors and attributes are the basis for predicted responses of the attributes to changes in the stressors. The linkages represent the present state of scientific knowledge of the ecosystem regarding causal effects of the hydrologic and water quality stressors on the attributes. The level of certainty in each linkage may vary from published causal relationships and models, to ongoing research and unpublished data, to research in comparable ecosystems, to field observations, to best professional judgement. Because large, complex ecosystems such as the Everglades may never be wholly understood or predictable based on research and modeling, the causal linkages represent working hypotheses with varying levels of certainty.

The levels of certainty in the conceptual ecological model linkages affect our ability to interpret ecological changes that are detected through the monitoring and assessment plan. Interpreting an ecosystem change during the implementation of CERP requires an understanding of the causal relationships of the ecological indicators to hydrology, water quality and other stressors that may be outside the influence of CERP. This will be particularly true when unexpected ecological responses occur. Understanding why unexpected responses occur will be fundamental to the role of adaptive assessment in guiding CERP throughout its implementation.

Assessment of the varying levels of certainty in the conceptual model linkages indicates strengths and weaknesses in the restoration expectations of CERP and in our ability to interpret ecological changes toward, or away from, those expectations. Low levels of certainty in the linkages identify highest-priority areas of research necessary to support and supplement the monitoring and assessment plan. Thus the conceptual models, and the levels of certainty in their linkages, yield a strategy for prioritized research and modeling, described in Section IV, that is driven by the adaptive assessment process.

The implementation of the monitoring and assessment plan will, over time, additionally help to raise the levels of certainties of CERP-related effects on the south Florida ecosystem.

(9) Perspectives on Successful Restoration

This section does not attempt to specifically answer the question of what is successful restoration. Rather it raises several key issues and identifies the key discussions that must occur on a continuing basis during the implementation of CERP, if a broad consensus regarding a collective vision of a successful restoration program is to be maintained and strengthened. To a large extent, the question of "what is successful restoration?" should strongly influence the decisions of "what should be monitored?".

The question of what is, or is not, successful restoration, is a complex issue, one that continues to be discussed by both scientists and the broader public. It is acknowledged that there currently is a range of definitions of "success" for CERP. The range of views on this question simply illustrates that there are many legitimate criteria that have been proposed for use in characterizing healthy, "restored" natural and human systems. Depending on which criteria are preferred, and there are different views on how the priorities should be set, there are different elements of these systems that can serve as indicators of successful restoration. Continuing discussion of these questions will result in the addition of new performance measures and in improvements to the existing set of measures.

CERP contains both natural system and human system goals. The performance measures and monitoring plan address an array of system-wide biological, ecological, water quality, water distribution, and depth and flow, water supply and flood protection objectives. Broadly stated, the success of CERP will have been achieved when the objectives described by the full suite of performance measures have been reached.

In the natural system, it is widely acknowledged that ultimate success should be determined through measures of ecological and biological responses. Hydrological and water quality objectives are essential precursors to the realization of the overall natural system restoration goals. How closely CERP must achieve these precursor objectives in order to meet its ecological objectives remains uncertain, in a system that is so greatly altered spatially, and where pre-drainage hydrological and ecological linkages are incompletely known.

A more pragmatic question is to ask how many, and which, of the total number of performance measures must be achieved before the plan is considered successful? And how closely to the desired objective that have been established for each measure does the plan's performance need to come? These questions over time will become more easily answered as understandings and agreements of what actually constitutes a healthy, "restored" natural system improve. The combined effects of continuing research coupled with improvements in public understandings of the natural systems of south Florida will inevitably lead to a growing consensus regarding the qualities of healthy

natural and human environments. The current Comprehensive Everglades Restoration Plan, according to modeling, is predicted to return the natural system to a hydrological and ecological condition that is well within the boundaries of a "restored system" as defined by the performance measures used during the Central and Southern Florida Restudy. CERP is predicted also to largely meet its water supply objectives. The role of the monitoring plan and the adaptive assessment process are to increase the chances that these predictions are correct, while at the same time "raising the bar" for the overall objectives of CERP.

(10) Adaptive Assessment Team Editorial Team Members

The following people served as members of the ad hoc editorial team that drafted the CERP system-wide monitoring and assessment plan. For additional information on the monitoring and assessment plan, contact either of the AAT co-chairs, Laura Brandt (laura_brandt@fws.gov) or Susan Gray (sgray@sfwmd.gov), or the SFWMD's RECOVER Program Manager, John Ogden (jogden@sfwmd.gov).

Tomma Barnes, South Florida Water Management District
Laura Brandt, U.S. Fish & Wildlife Service
Cheryl Buckingham, U.S. Army Corps of Engineers
Steve Davis, South Florida Water Management District
Juan Diaz-Carreras, South Florida Water Management District
Mike Duever, South Florida Water Management District
Susan Gray, South Florida Water Management District
Eric Hughes, U.S. Environmental Protection Agency
Linda Lindstrom, South Florida Water Management District
Agnes McLean, South Florida Water Management District
Brenda Mills, South Florida Water Management District
John Ogden, South Florida Water Management District
Joe Walsh, Florida Fish & Wildlife Conservation Commission